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Simpson

INSTRUMENTS THAT STAY ACCURATE

OPERATOR'S MANUAL

SIMPSON 464 SERIES 3 DIGITAL MULTIMETER

WARNING

For safe usage, it is essential that the operator read this manual carefully before using the instrument for any measurements.

SIMPSON ELECTRIC COMPANY
853 Dundee Ave., Elgin, Illinois 60120
Area Code 312, Telephone 697-2260
In Canada, Bach-Simpson, Ltd., London, Ontario

DIGITAL INSTRUMENT
Warranty

SIMPSON ELECTRIC COMPANY warrants each digital instrument manufactured by it to be free from defects in material and workmanship under normal use and service, its obligation under this warranty being limited to making good at its factory any digital instrument which shall within one (1) year after delivery of such instrument or other article of equipment to the original purchaser be returned intact to it, or to one of its authorized service stations, with transportation charges prepaid, and which its examination shall disclose to its satisfaction to have been thus defective; this warranty being expressly in lieu of all other warranties expressed or implied and of all other obligations or liabilities on its part, and SIMPSON ELECTRIC COMPANY neither assumes nor authorizes any other persons to assume for it any other liability in connection with the sale of its products.

This warranty shall not apply to any digital instrument which shall have been repaired or altered outside the SIMPSON ELECTRIC COMPANY factory or authorized service stations, nor which has been subject to misuse, negligence or accident, incorrect wiring by others, or installation or use not in accord with instructions furnished by the manufacturer.

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ELECTRIC COMPANY
853 Dundee Ave., Elgin, Illinois 60120 Phone: (312) 697-2260
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KATY INDUSTRIES
INDUSTRIAL EQUIPMENT GROUP

OPERATOR'S MANUAL

SIMPSON 464 DIGITAL MULTIMETER

This symbol on the nameplate means the product is Listed by Underwriters Laboratories Inc.

SIMPSON ELECTRIC COMPANY
853 Dundee Ave., Elgin, Illinois 60120
Area Code 312, Telephone 697-2260
In Canada, Bach-Simpson, Ltd., London, Ontario

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NOTE: This Operator's Manual contains information essential to the operation of this Instrument. Therefore, it should be kept in a convenient place and used for reference as required.

SAFETY SYMBOLS

This marking adjacent to another marking or a terminal or operating device indicates that the Operator must refer to an explanation in the Operating Instructions to avoid damage to the equipment and/or to avoid personal injury.

WARNING

The WARNING sign denotes a hazard. It calls attention to a procedure, practice, or the like, which if not correctly performed or adhered to, could result in personal injury.

CAUTION

The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which if not correctly adhered to could result in damage to or destruction of part or all of the Instrument.

WARNING

This Instrument is designed to prevent accidental shock to the operator when properly used. However, no engineering design can render safe an instrument which is used carelessly. Therefore, this manual must be read carefully and completely before making any measurements. Failure to follow directions can result in a serious or fatal accident.

SHOCK HAZARD: As defined in American National Standard, C39.5, Safety Requirements for Electrical & Electronic Measuring & Controlling Instrumentation, a shock hazard shall be considered to exist at any part involving a potential in excess of 30 volts rms (sine wave) or 42.4 volts DC or peak and where a leakage current from that part to ground exceeds 0.5 milliampere, when measured with an appropriate measuring instrument defined in Section 11.6.1 of ANSI C39.5.

NOTE: The proper measuring instrument for the measurement of leakage consists essentially of a network of a 1500 ohm non-inductive resistor shunted by a 0.15 microfarad capacitor connected between the terminals of the measuring instrument. The leakage current is that portion of the current that flows through the resistor. The Simpson 229-Series 2 AC Leakage Current Tester meets the ANSI C39.5 requirements for the measurement of AC leakage current and can be used for this purpose. To measure DC Leakage current, connect a 1500 ohm non-inductive resistor in series with a Simpson 0-500 DC microammeter and use this as the measuring instrument.

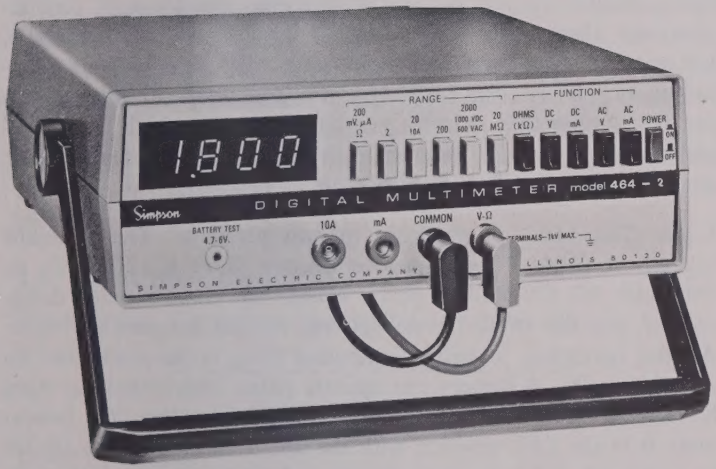


Figure 1-1. 464 Digital Multimeter

SECTION I
INTRODUCTION

1.1 GENERAL

1.1.1 The Simpson 464 _ Digital Multimeter (hereafter referred to as the 464 or the Instrument) is a compact, 3½ digit instrument, suitable for use in general electronic maintenance, production, and laboratory work. It features 0.1 percent DCV accuracy, integrated circuit electronics, solid-state LED display, and push-button switch selection for ranges and functions. Additional features are automatic polarity, automatic zeroing, high input impedance (for voltage measurements), and excellent temperature and over-ranging characteristics.

1.1.2 The 464 is available in two versions: The standard instrument (464A) designed to operate from a 120, 220, or 240 volts AC (50-400Hz) power source (check rear panel designation); and the 464D is an optional version designed for either AC line operation, or battery operation using rechargeable nickel-cadmium cells. A battery can operate either Instrument for eight hours continuously. Recharging is automatic when the Instrument is in the OFF position with the line cord connected. (Refer to paragraph 6.5.1 for precautions and instructions). Hereafter, all information and data applied to both instruments.

1.1.3 The 464 (Figure 1-1) measures DC voltage, AC voltage, DC current, AC current and resistance as specified in Table 1-1. The charge-balance integration technique is used for the analog-to-digital (A/D) conversion circuitry and is contained in two Large-Scale-Integration (LSI) modules, which provide high reliability and compact design.

1.2 ITEMS AND ACCESSORIES

1.2.1 All items and accessories required for the operation of

the 464 are furnished with each Instrument, and listed in the accompanying Table 1-2. (Available replacement parts are listed in Table 6-2.)

1.3 SAFETY CONSIDERATIONS

1.3.1 This Operator's Manual contains cautions and warnings alerting the user to hazardous operating and service conditions. This information is flagged by CAUTION or WARNING headings throughout this publication, where applicable, and are defined at the front of the manual under SAFETY SYMBOLS. To ensure the safety of operating and servicing personnel and to retain the operating conditions of the instrument these instructions must be adhered to.

1.4 TECHNICAL DATA

1.4.1 Table 1-1 lists the technical data for the 464 .

Table 1-1. Technical Data

1. DC VOLTAGE:

Range	Maximum Indication	Input Resistance	Overload Protected To
200 mV	±199.9 mV	10 MΩ	±1000V
2V	±1.999V	10 MΩ	±1000V
20V	±19.99V	10 MΩ	±1000V
200V	±199.9V	10 MΩ	±1000V
1000V	±1000V (Max. Input)	10 MΩ	±1000V

Accuracy (from +15°C to +35°C): ± (0.1% of reading + 1 digit)

Input Bias Current: 40 pA at reference conditions

Sensitivity: 100 μV on 200 mV range

Full Range Step Response (to rated accuracy): 1 second, maximum

Normal Mode Rejection:	55 dB minimum at 60 Hz
Common Mode Rejection:	90 dB minimum at 60 Hz
Overrange Capability:	Linear to 1000 counts beyond maximum indication (except on 1000V range, where any indication greater than 1000 is an overload)
Temperature Coefficient (from 0°C to +55°C):	± (0.01% of reading + 0.05 digit)/°C

2. AC VOLTAGE:

(Average-Sensing, rms Calibrated Sine Wave 40 Hz to 10 kHz)

Range	Maximum Indication	Input Impedance	Overload Protected To
200 mV	199.9 mV	10 MΩ and 75 pF	600V rms
2V	1.999V	10 MΩ and 75 pF	600V rms
20V	19.99V	10 MΩ and 75 pF	600V rms
200V	199.9V	10 MΩ and 75 pF	600V rms
600V*	600V (Max. Input)	10 MΩ and 75 pF	600V rms

Accuracy (from +15°C to +35°C):	±(0.5% of reading + 2 digits), 40 Hz to 1000 Hz ±(1.0% of reading + 2 digits), 1000 Hz to 10 kHz
Sensitivity:	100 μV on 200 mV range
Full Range Step Response (to rated accuracy):	5 seconds, maximum
Temperature Coefficient (from 0°C to +55°C):	±(0.05% of reading + 0.05 digit)/°C

**Frequency Range: 40 Hz to 1000 Hz.*

3. RESISTANCE:

Range	Maximum Indication	Full Scale Voltage	Test Current	Overload Protected To
200 Ω	199.9 Ω	200 mV	1 mA	135V rms
2 kΩ	1.999 kΩ	2V	1 mA	135V rms

20 kΩ	19.99 kΩ	2V	100 μA	250V rms
200 kΩ	199.9 kΩ	200 mV	1 μA	250V rms
2000 kΩ	1999 kΩ	2V	1 μA	250V rms
20 MΩ	19.99 MΩ	2V	100 nA	250V rms

Accuracy
(from +15°C to +35°C): ±(0.5% of reading + 1 digit) except on the 20 MΩ range, which is ±(1.0% of reading + 1 digit)

Sensitivity: 0.1Ω on 200Ω range

Full Range Step
Response (to rated accuracy): 2 seconds, except on 20 MΩ range, which is 7 seconds

Temperature Coefficient
(from 0°C to +55°C): ±(0.05% of reading + 0.05 digit)/°C

4. DC CURRENT:

Range	Maximum Indication	Full Range Voltage Drop	Overload Protected To
200 μA	±199.9 μA	200 mV	±2.5A*
2 mA	±1.999 mA	200 mV	±2.5A*
20 mA	±19.99 mA	200 mV	±2.5A*
200 mA	±199.9 mA	200 mV	±2.5A*
2000 mA	±1999 mA	200 mV	±2.5A*
10 A	±10.00 A (Max. Input)	100 mV	±10A

**Fuse Protected.*

Accuracy
(from +15°C to +35°C): ±(0.5% of reading + 1 digit), except on 2000 mA and 10A ranges, which are ±(1.0% of reading + 1 digit)

Sensitivity: 100 nA on 200 μA range

Full Range Step
Response (to rated accuracy): 1 second

Temperature Coefficient
(from 0°C to +55°C): ±(0.05% of reading + 0.05 digit)/°C

Overrange Capability: Linear to 500 counts beyond maximum indication (except on 10A range, where any indication greater than 1000 is an overload).

5. AC CURRENT (40 Hz to 10 kHz):

Range	Maximum Indication	Full Range Voltage Drop	Overload Protected To
200 μA	199.9 μA	200 mV	2.5A*
2 mA	1.999 mA	200 mV	2.5A*
20 mA	19.99 mA	200 mV	2.5A*
200 mA	199.9 mA	200 mV	2.5A*
2000 mA	1999 mA	200 mV	2.5A*
10 A	10.00A (Max. Input)	100 mV	10A

**Fuse Protected.*

Accuracy (from +15°C to +35°C): ±(1.5% of reading + 2 digits), except on 2000 mA and 10A ranges, which are ±(2.0% of reading + 2 digits)

Sensitivity: 100 nA on 200 μA range

Full Range Step Response (to rated accuracy): 5 seconds, maximum

Temperature Coefficient (from 0°C to +55°C): ±(0.1% of reading + 0.1 digit)/°C

Overrange Capability: Linear to 500 counts beyond maximum indication (except on 10A range, where any indication greater than 1000 is an overload).

6. RATED CIRCUIT-TO-GROUND VOLTAGE:

(Maximum Common Mode Voltage) ⚠ 1000 volts (DC plus peak AC) maximum from any measuring terminal to power-line (earth) ground terminal, except on 10A ranges, which is 50 volts maximum.

7. RESOLUTION: 1 part in 2000

8. DISPLAY:

Numerical Display:	3½ digit, 7- segment light-emitting-diode (LED) type, with flashing digits for counts over 1999.
Conversion Rate:	3 readings per second, nominal
DC Polarity Selection:	Automatic with "+" or "—" indication

9. POWER REQUIREMENT:

AC Operating (464A) or Battery Charging (464D):	120 VAC, 220 VAC, and 240 VAC ±10% (check rear panel designation), 50-400 Hz 5 VA nominal
Battery Operation (464D):	Four nickel-cadmium "D" size rechargeable cells. Eveready type CH4 or equivalent (each cell is rated at 1.25V, 4-ampere hours)
Battery Operation Time: (continuous with fully charged battery)	8 hours, nominal
Battery Recharge Time:	16 hours, nominal

10. TEMPERATURE RANGE:

Operating:	0°C to +55°C
Storage:	−40°C to +60°C

11. RELATIVE HUMIDITY: 0 to 90% (non-condensing)

12. REFERENCE CONDITIONS:

Temperature:	+23°C ±1°C
Relative Humidity:	30 to 60%
Atmospheric Pressure:	575 to 800 mmHg

13. DIMENSIONS:

Height:	2.70 in. (68.6 mm)
Width:	8.40 in. (213.4 mm)
Depth:	9.00 in. (228.6 mm)

14. WEIGHT: Approximately 3 lbs. (1.36 kg)

Table 1-2. Items and Accessories Furnished With This Instrument

Quantity	Description	Part No.
1	Test Lead Set: One black and one red insulated lead having probe tips with provisions for screw-on alligator clips (one red and one black supplied).	10-864590
1	Power Cord	5-118916
1	Operator's Manual	6-111763

SECTION II
INSTALLATION

2.1 GENERAL

2.1.1 This section contains information and instructions for the installation and shipping of the 464 . Included are unpacking and inspection procedures, warranty, shipping, power source requirements, installation and care.

2.2 UNPACKING AND INSPECTION

2.2.1 Examine the shipping carton for obvious signs of damage. Inspect the Instrument for possible damage incurred during shipment. If damage is noted, notify the carrier and supplier and do not attempt further use of the Instrument. If Instrument appears to be in good condition, read Operator's Manual in its entirety. Become familiar with the Instrument as instructed in the manual, then proceed to check the electrical performance as soon as possible. Also, check that all items are included with the Instrument (Table 1-2).

2.2.2 Save the shipping carton and packing materials for future storing or shipping of the Instrument.

2.3 WARRANTY

2.3.1 The Simpson Electric Company warranty policy is printed on the inside front cover of this manual. Read it carefully prior to requesting a warranty repair.

> **NOTE:** For assistance of any kind, including help with the Instrument under warranty, contact the nearest Authorized Service Center for instructions (listed on the last pages of this manual). If it's necessary to contact the factory directly, give full details of any difficulty and include the Instrument model number, serial number (at the back of the Instrument) and date of purchase.

Service data or shipping instructions will be mailed promptly. If an estimate of charges for non-warranty or other service work is required, a maximum charge estimate will be quoted. This charge will not be exceeded without prior approval.

2.4 SHIPPING

2.4.1 Pack the Instrument carefully and ship it prepaid to the proper destination. Insure the Instrument.

2.5 POWER SOURCE REQUIREMENTS

2.5.1 The 464A is designed to be operated from the AC line. The 464D is designed to be operated from either the AC line or self-contained nickel-cadmium cells (not furnished with the Instrument but available from any local electronic parts distributor. Refer to Table 1-1, item 9.)

2.5.2 AC Line Operation

2.5.3 The 464 is wired at the factory for 120 VAC (50-400Hz) operation. To convert your Instrument for 220 VAC or 240 VAC operation, consult the nearest Authorized Service Center.

CAUTION

For AC line operation, ensure that the grounding pin of the power plug is securely connected to an earth (power-line) ground. Use a 3-wire grounded outlet which conforms to the latest electrical code.

2.5.4 Battery Operation (464D .)

2.5.5 Battery operation is automatic whenever cells are installed,

the line cord is disconnected, and one of the FUNCTION switches set to a position other than the POWER OFF Position. (For battery installation and battery test refer to paragraph 6.5.)

2.6 INSTALLATION

2.6.1 The Instrument may be set horizontally on its four rubber feet or vertically on its back and operated in either position. The Instrument can also be set at an inclined angle by positioning the 8-position carrying handle under the unit. To set the Instrument at a desirable viewing angle, use the following procedure:

a. Pull out both knobs on sides of Instrument.

b. Rotate handle to one of eight positions.

c. Push both knobs into a locking position.

2.7 CARE

WARNING

Do not attempt to clean this Instrument with the test leads connected to a power source or when it is connected to the AC powerline.

2.7.1 Immediately clean all spilled materials from the Instrument and wipe dry. If necessary, moisten a cloth with soap and water to clean plastic surfaces.

2.7.2 Do not allow the battery to fully discharge. A completely discharged battery generally becomes inoperative and a replacement will be necessary. Check the battery voltage according to paragraph 4.3.2.

2.7.3 Whenever possible, avoid exposure or usage in areas which

are subject to temperature and humidity extremes, vibration, mechanical shock, dust, corrosive fumes, or strong electrical or electromagnetic interferences.

2.7.4 Monthly Care: Verify Instrument calibration by performing operational checks using known value sources. If the need for calibration is indicated, contact the nearest Authorized Service Center.

2.7.5 Annual Care: It is recommended that the Instrument be returned annually to an Authorized Service Center or the factory for a complete overall check and calibration.

2.7.6 Storage: When the Instrument is not in use, store it in a location free from temperature extremes, dust and corrosive fumes, and mechanical vibration or shock.

SECTION III
CONTROLS, CONNECTORS, AND INDICATORS

3.1 GENERAL

3.1.1 All operating and adjusting controls, connectors, and indicators are described in Table 3-1. Become familiar with each item prior to operating the Instrument for the first time.

3.2 FRONT AND REAR PANEL DESCRIPTION

3.2.1 Table 3-1 lists all front and rear panel controls, connectors, and indicators (Figure 3-1 and 3-2).

Table 3-1. Front and Rear Panel Description

1. POWER Switch:	
ON ▬	Applies primary power to the Instrument.
OFF ▬	Disconnects primary power from all circuits except the battery charging circuit.
2. FUNCTION Switches:	
Position	
AC mA	Connects the COMMON and mA jacks to the AC current measuring circuits.
AC V	Connects the COMMON and V-Ω jacks to the AC voltage measuring circuits.
DC mA	Connects the COMMON and mA jacks to the DC current measuring circuits.
DC V	Connects COMMON and V-Ω jacks to the DC voltage measuring circuits.
OHMS (kΩ)	Connects the COMMON and V-Ω jacks to the resistance measuring circuits.
3. RANGE Switches:	
Position	
200 mV, μA Ω	Selects the circuits required for full range measurements of 0 to ± 200 mV DC, 0 to 200 mV AC, 0 to ± 200 μA DC, 0 to 200 μA AC, 0 to 200 ohms, depending on the function switch selected.

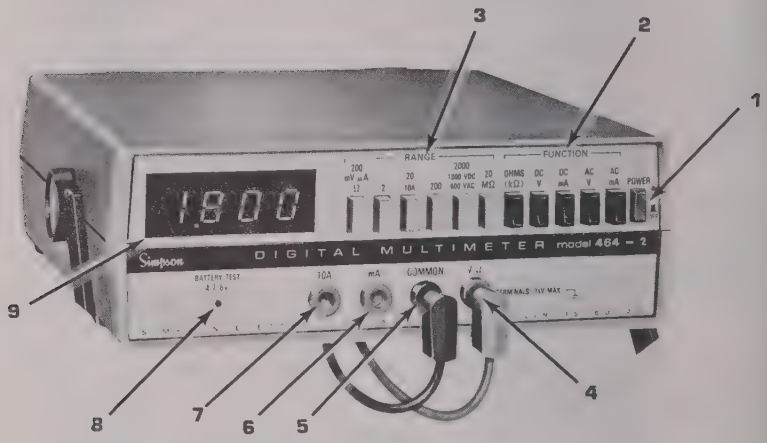


Figure 3-1. Front Panel Description

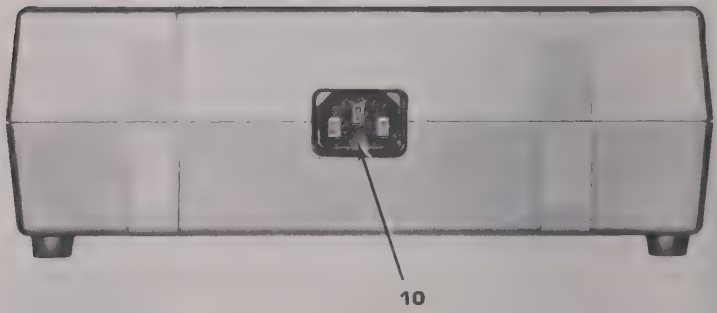


Figure 3-2. Rear Panel Description

2,
20
10A,
200,
2000
1000 VDC
600 VDC

Selects the circuits required for full range measurements of 0 to the corresponding numerical values of AC mA, ±DC mA, Ω, ±DC V or AC V depending on the function switch selected.

20 MΩ

Selects the circuits required for the full range measurement of resistance from 0 to 20 MΩ when the function switch OHMS (kΩ) is selected.

4. V-Ω Jack:

This terminal is used to connect the "high" side of the circuit being measured to all voltage and resistance measuring circuits through the range and function switches.

5. COMMON Jack:

This jack is used to connect the "low" side of the circuit measured to the internal circuit COMMON and is isolated from the AC powerline ground.

6. mA Jack:

This terminal is used to connect the "high" side of the currents being measured to the current measuring circuits through the FUNCTION and RANGE switches. The "low" side is connected to the COMMON jack.

7. 10A Jack:

This terminal is used to connect the "high" side of the 10 ampere full scale currents being measured to the current measuring circuits when RANGE switch 20 (10A) and function switch DC mA or AC mA are selected. The "low" side is connected to the COMMON jack.

8. BATTERY TEST
4.7-6V
(464D only):

This jack connects to the positive terminal of the battery installed. For battery test, connect a test lead between the V-Ω jack and the BATTERY TEST jack with the function switch DCV and the RANGE switch 20 (10A) selected. The numerical display must indicate a voltage between +4.7 volts and +6.0 volts for proper operation. If the display indicates greater than +6.0 volts, either the battery is not installed or the battery is not installed properly.

9. Numerical Display: The digital display uses LED's and includes a polarity (+, —) sign, a "1" digit, three 7-segment type 0 to 9 digits and a decimal point, to indicate the polarity and the value of the signal being measured. The decimal point is properly positioned by the selection of the range switch. Over-range (or out-of-range) condition is indicated by a flashing display for 2000 counts or greater.

10. AC Power Receptacle: This receptacle accepts the AC line power cord used for AC operation or battery charging.

SECTION IV
OPERATION

4.1 GENERAL

WARNING

Before proceeding with the operation of the 464 review the SHOCK HAZARD at the front of this manual.

4.2 SAFETY PRECAUTIONS

4.2.1 The 464 is designed to be used only by personnel qualified to recognize shock hazards and trained in the safety precautions required to avoid possible injury.

4.2.2 Do not work alone when making measurements where a shock hazard can exist. Notify another person that you are, or intend to make such measurements.

REMEMBER: Voltages might appear unexpectedly in defective equipment. An open bleeder resistor can result in a capacitor retaining a dangerous charge. Remove all power and discharge all capacitors in the circuit being measured and remove all power from the 464 before making connections or disconnections. The Instrument itself is well protected against electrical overload, as noted throughout Table 1-1. However, the above precautions are wise even in the laboratory, and especially in field usage of the Instrument where many unknown safety hazards might prevail.

4.2.3 Locate all voltage sources and accessibility paths prior to making any measurements or connections.

4.2.4 Before each use, inspect the test leads, prods, connectors and power cable for cracks, breaks, or crazes in the insulation. If any defects exist, destroy and replace the defective item(s) immediately.

4.2.5 Do not make measurements in a circuit where corona is present. Corona can be identified by a pale-blue color emanating from sharp metal points in the circuit or a buzzing sound, or the odor of ozone. In rare instances, such as around germicidal lamps, ozone might be generated as a normal function. Ordinarily, the presence of ozone indicates presence of high voltage, and probably a malfunction of some kind.

4.2.6 Hand, shoes, floor, and workbench must be dry. Avoid making measurements under humid, damp, or other environmental conditions that could affect the dielectric withstanding voltage of the test leads of the Instrument.

4.2.7 Do not touch test leads, circuits, or Instrument while power is applied to the circuit being measured.

4.2.8 Use extreme caution when making measurements where dangerous composite voltages could be present, such as in an rf amplifier.

4.2.9 Do not use test leads which differ from those originally furnished with the Instrument.

4.2.10 Before the Instrument is used for AC operation, make sure that the "third wire" on the AC power cord is connected to an earth or powerline ground.

4.2.11 Do not float any measuring terminal more than 1000 volts (DC plus AC peak) with respect to the powerline or earth ground.

4.3 PRELIMINARY NOTES AND CHECKS

NOTE: Prior to operation of the Instrument, review and perform (where applicable) the following notes and checks. These steps can be used also as a general functional check.

4.3.1 For AC Line operation:

a. Ensure that the power source used matches the requirements of the Instrument as marked on the rear panel.

b. Insert the plug into a 3-wire power outlet which conforms to the latest electrical code. The 464D will operate with or without battery power. When the 464D is operating on the AC line with the internal battery installed, the battery is being "trickle" charged.

4.3.2 For the 464D battery operation follow this procedure:

CAUTION

Do not operate the Instrument with cells in the completely discharged state, which is common for all new cells as acquired from the vendor (Paragraph 6-4).

a. Disconnect the AC line cord and set the POWER switch to the OFF position. Install four "D" size nickel-cadmium cells (not supplied with Instrument). Observe polarity as shown on label inside battery holder. Assemble case and turn unit ON.

b. Depress the DCV function and 20 (10A) range switches.

c. Connect a test lead between the V-Ω jack and the BATTERY TEST jack. The reading must be between +4.7 volts and +6.0 volts for proper operation of the Instrument.

d. If the battery voltage is below +4.7 volts, or if the display does not emit light, either the battery is improperly installed or recharging is required.

> **NOTE:** If the battery is not installed, or not installed properly, the BATTERY TEST reading will be greater than +6 volts. This voltage is the open-circuit charging voltage for the battery.

4.3.3 To recharge the battery, follow this procedure:

a. Set the POWER switch to the OFF position. Connect the line cord plug into a 3-wire outlet which conforms to the power requirements of the Instrument as marked on the rear panel, and to the latest electrical code.

b. The battery is being charged at full rate.

> **NOTE:** If the battery test indicates a voltage below +4.7 volts, set the POWER switch in the OFF position for at least 15 minutes before operating.

4.4 GENERAL FUNCTIONAL CHECK:

a. Review the safety precautions in paragraph 4.2.

b. Connect the black test lead to the COMMON jack and the red test lead to the V-Ω jack. Short the test leads together.

c. Depress and set the OHMS (KΩ) function and 2 range switches.

d. Open the test leads. The numerical display will be flashing in the out-of-range condition.

e. Short the test leads together. The display reading will return to 0.000 ± 1 digit.

f. If difficulty is encountered in the above steps, see Section VI.

4.5 DC VOLTAGE MEASUREMENTS:

a. Review the safety precautions in paragraph 4.2.

b. Connect input test leads to the V-Ω and COMMON terminals.

c. Depress DCV function switch.

d. Depress the appropriate voltage range switch as indicated in Table 4-1. If the voltage being measured is unknown, begin with the 1000 range VDC switch.

Table 4-1. DC Voltage Ranges and Connections

Range	Range Switch	Function Switch	Input Connections	Max. Voltage	Remarks
0 to ±200 mV	200 mV	DCV	V-Ω, COMMON	±1000	Auto-Polarity on all ranges.
0 to ±2V	2	DCV	V-Ω, COMMON	±1000	
0 to ±20V	20	DCV	V-Ω, COMMON	±1000	
0 to ±200V	200	DCV	V-Ω, COMMON	±1000	
0 to ±1000V	1000	DCV	V-Ω, COMMON	±1000	

e. Turn off the power to the device or circuit under test and discharge all capacitors.

CAUTION

Do not attempt to measure voltages on the 1000 VDC range which might be greater than 1000 volts DC.

f. Connect test leads to the circuit being measured.

g. Apply power to the circuit being measured. The Instrument

will automatically indicate the correct polarity. The value of the voltage being measured will be indicated on the numerical display.

h. Remove all power from the circuit being measured and discharge all capacitors prior to disconnecting test leads.

4.6 AC VOLTAGE MEASUREMENT

a. Review safety precautions in paragraph 4.2.

b. Connect input test leads to the V-Ω and COMMON terminals.

c. Depress the ACV function switch.

d. Depress the appropriate voltage range switch as indicated in Table 4-2. If the voltage being measured is unknown, begin with the 600 range VAC switch.

CAUTION

Do not attempt to measure voltages on the 600 VAC range which might be greater than 600 volts.

Table 4-2. AC Voltage Ranges and Connections

Range	Range Switch	Function Switch	Input Connections	Max. Voltage	Frequency Range
0-200 mV	200 mV	ACV	V-Ω, COMMON	600V rms	40Hz-10kHz
0-2V	2	ACV	V-Ω, COMMON	600V rms	40Hz-10kHz
0-20V	20	ACV	V-Ω, COMMON	600V rms	40Hz-10kHz
0-200V	200	ACV	V-Ω, COMMON	600V rms	40Hz-10kHz
0-600V	600 VAC	ACV	V-Ω, COMMON	600V rms	40Hz- 1kHz

e. Remove all power from the circuit being measured and discharge all capacitors.

f. Connect test leads to the circuit being measured.

g. Apply power to the circuit being measured. The value of the voltage being measured will be indicated on the numerical display.

h. Remove all power from the circuit being measured and discharge all capacitors prior to disconnecting test leads.

4.7 RESISTANCE MEASUREMENTS:

a. Review the Preliminary Notes and Checks in paragraph 4.3.

b. Connect input test leads to the V-Ω and COMMON terminals.

c. Depress the OHMS (KΩ) function switch.

d. Depress the appropriate resistance range switches as indicated in Table 4-3.

e. If the resistance being measured is connected into a circuit, be certain that all power is removed from the circuit and all capacitors are discharged. Check for current paths other than through the resistance being measured. These paths can result in a measured value which is lower than the actual value of the resistance being measured.

f. Connect the test leads to the resistance being measured. Be careful not to contact adjacent points, even if insulated, particularly when making high resistance measurements. Some insulators can have relatively low insulation resistance, which can sufficiently shunt the resistance being measured to result in a measured value lower than the presumed value.

> **NOTE:** If the resistance being measured is polarity or voltage sensitive (for example, semiconductors), careful consideration must be given when making connections and selecting the resistance range (Table 4-3).

g. Allow time for the display to stabilize. This procedure is especially important when measuring a high value resistance shunted by a large value of capacitance.
h. Disconnect test leads.

Table 4-3. Resistance Ranges and Connections

Range	Range Switch	Function Switch	Input Connections	Test Current	Full Scale Voltage
0 to 200Ω	200Ω	OHMS	V-Ω, COMMON	1 mA	200 mV
0 to 2 kΩ	2	OHMS	V-Ω, COMMON	1 mA	2 V
0 to 20 kΩ	20	OHMS	V-Ω, COMMON	100 μA	2 V
0 to 200 kΩ	200	OHMS	V-Ω, COMMON	1 μA	200 mV
0 to 2000 kΩ	2000	OHMS	V-Ω, COMMON	1 μA	2 V
0 to 20 MΩ	20 MΩ	OHMS	V-Ω, COMMON	100 nA	2 V

4.8 DC CURRENT MEASUREMENTS:

a. Review Safety Precautions in paragraph 4.2.
b. Depress the DC mA function switch.
c. Depress the appropriate current range switch as indicated in Table 4-4. If the current being measured is unknown (but less than 10A), begin with the 20 (10A) switch and connect the red test lead to the 10A jack and the black test lead to the COMMON jack.
d. Remove all power to the circuit being measured and discharge all capacitors.
e. Connect the test leads according to Table 4-4.
f. Open the circuit in which the current is to be measured and securely connect the test leads in series. Ensure that the 464 is not connected across a voltage source which can exceed ratings of the Instrument.

Table 4-4. DC Current Ranges and Connections

Range	Range Switch	Function Switch	Input Connections	Max. Current Amperes	Remarks
0 to ±200 μA	200 μA	DCmA	mA, COMMON	±2.5	Auto-Polarity on all ranges.
0 to ±2 mA	2	DCmA	mA, COMMON	±2.5	
0 to ±20 mA	20 10A	DCmA	mA, COMMON	±2.5	
0 to ±200 mA	200	DCmA	mA, COMMON	±2.5	
0 to ±2000 mA	2000	DCmA	mA, COMMON	±2.5	
0 to ±10A	20 10A	DCmA	10A, COMMON	±10	

g. Apply power to the circuit being measured.

h. The value of the current being measured is indicated on the numerical display.

i. Remove all power from the circuit being measured and discharge all capacitors.

j. Disconnect the test leads and reconnect the circuit which was originally opened.

4.9 AC CURRENT MEASUREMENTS:

a. Review Safety Precautions in Paragraph 4.2.

b. Depress ACmA function switch.

c. Depress the appropriate current range switch as indicated in Table 4-5. If the current being measured is unknown (but less than 10A), begin with the 20 (10A) switch and connect the red test lead to the 10A jack and the black test lead to the COMMON jack.

d. Remove all power from the circuit being measured and discharge all capacitors.

Table 4-5. AC Current Ranges and Connections

Range	Range Switch	Function Switch	Input Connections	Max. Current Amperes	Remarks
0 to 200 μA	200 μA	AC mA	mA, COMMON	2.5	Frequency range: 40 Hz to 10 Hz
0 to 2 mA	2	AC mA	mA, COMMON	2.5	
0 to 20 mA	20	AC mA	mA, COMMON	2.5	
0 to 200 mA	200	AC mA	mA, COMMON	2.5	
0 to 2000 mA	2000	AC mA	mA, COMMON	2.5	
0 to 10A	20 10A	AC mA	10A, COMMON	10	

e. Open the circuit in which the current is to be measured and securely connect the test leads in series. Ensure that the 464 is not connected across a voltage source which can exceed ratings of the Instrument.

f. Connect the test leads according to Table 4-5.

g. Apply power to the circuit being measured.

h. The value of the current being measured is indicated on the numerical display.

i. Remove all power from the circuit being measured and discharge all capacitors.

j. Disconnect the test leads and reconnect the circuit which was originally opened.

SECTION V
THEORY OF OPERATION

5.1 OVERALL SYSTEM

5.1.1. The basic system block diagram for the 464 is shown in Figure 5-1.

5.1.2 Signal Conditioning Section

5.1.3 The parameter being measured is connected to the appropriate input terminals. The corresponding Signal Conditioning circuits convert this parameter into a proportional DC voltage. The conversion is accomplished by the Attenuator, Current Shunts, Resistance Converter, AC-to-DC Converter, and the associated switching.

5.1.4 The Analog-To-Digital Converter Section

5.1.5 The Analog-To-Digital (A/D) Converter section changes the DC output voltage from the Signal Conditioning section to digital information. Using two Large-Scale Integration (LSI) circuits, the unique A/D converter automatically eliminates zero error.

5.1.6 Display Section

5.1.7 Digital information in BCD form from the A/D Converter section is decoded into 7-segment information by the Decoder/Driver. The decoded information, in conjunction with the Anode Drivers, is visually presented on the Numerical Display.

5.2 INPUT CIRCUITS

5.2.1 DC Voltage Measurements

5.2.2 The basic DC voltage measurement circuit is shown in Figure 5-2(A). The DC voltage being measured is connected to

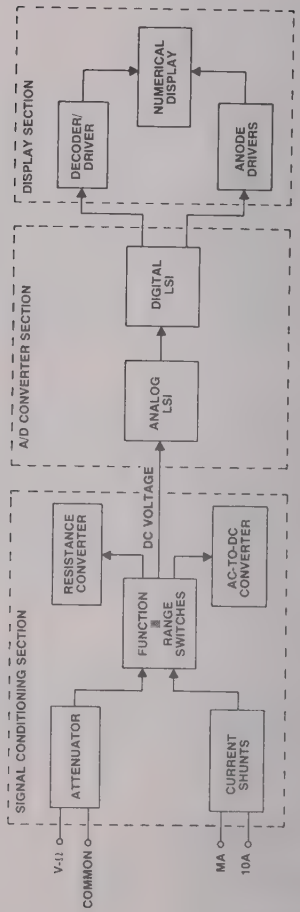


Figure 5-1. Basic System Block Diagram

the V-Ω and COMMON jacks, attenuated according to the range selected and converted into digital information by the A/D Converter.

5.2.3 The A/D Converter circuit provides two basic full range sensitivities: 200 mV and 2V. This feature simplifies the attenuator design. No attenuator is required on the 200 mV and 2V ranges. The same attenuator ratio is used on the 20V and 200V ranges. A separate attenuator tap is provided for the 1000 volt range.

5.2.4 AC Voltage Measurement

5.2.5 The basic AC voltage measurement circuit is shown in Figure 5-2 (B). The AC voltage being measured is connected to the V-Ω and COMMON jacks, attenuated according to the range selected and applied to the amplifier. The output of the amplifier is converted into DC voltage by an active rectifier and the resulting DC voltage measured by the A/D Converter.

5.2.6 The AC-TO-DC Converter provides two basic full range sensitivities: 200 mV and 2V. The converter is average responding but its calibration (gain) is based on the rms value of a sine wave.

5.2.7 The AC-TO-DC Converter consists of an input amplifier and a precision half-wave active rectifier. The input amplifier, connected as a source follower, operates as a buffer for the active rectifier. The buffered output is applied as a voltage, Ein, to the non-inverting input of the operational amplifier. Negative feedback causes the voltage at the inverting input to follow the non-inverting input, causing a current Ein/R2, through R2 to circuit common. Since diodes CR1 and CR2 conduct on alternate half cycles, one-half of the average current flows through R1. The rectified voltage developed across R1 is filtered by the RC filter to produce the DC voltage required for the A/D Converter.

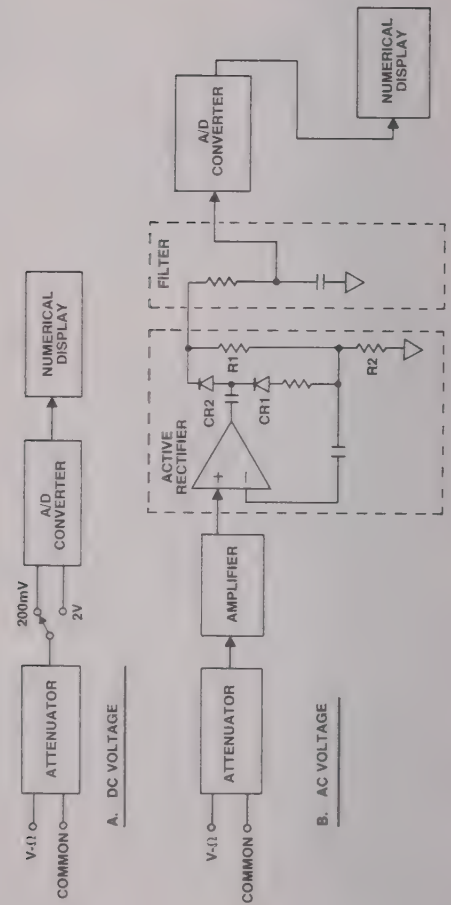


Figure 5-2. Basic Voltage Measurements Circuits

5.2.8 DC Current Measurements

5.2.9 The basic DC current measurement circuit is shown in Figure 5-3(A). The current being measured is connected in series with the mA (or 10A) and COMMON jacks, across an internal precision shunt resistance. The value of the shunt resistance depends on the current range selected. The DC voltage developed across the shunt resistor is measured by the A/D Converter.

5.2.10 The full range sensitivity of the A/D Converter is set for 200 mV. The internal shunt resistance for each current equals 200 mV divided by the full range current. For example, if the full range current is 200 µA, the shunt resistance is 1000 ohms.

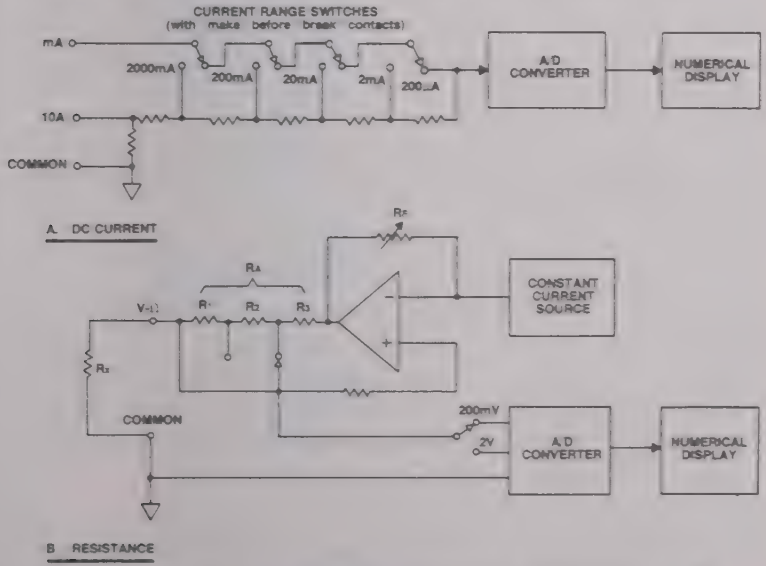


Figure 5-3. Basic DC Current and Resistance Measurement Circuits

5.2.11 AC Current Measurements

5.2.12 The basic AC current measurement circuit is essentially the same as the DC current measurement circuit (paragraph 5.2.6), except that the voltage developed across the internal shunt resistance is measured by the AC voltage measurement circuit.

5.2.13 Resistance Measurements

5.2.14 The basic resistance circuit is shown in Figure 5-3(B). The resistance being measured, Rx, is connected to the V-Ω and COMMON jacks and a constant current is applied through it by the Instrument. The resulting voltage is proportional to the value of Rx.

5.2.15 The operational amplifier bootstraps the constant current source. With the non-inverting input connected to the junction of Ra and Rx such that a constant voltage is maintained across Ra for a given range. The voltage developed is proportional to the value of Rx. For resistance ranges 200Ω through 2000 kΩ, the constant voltage maintained across Ra is 10 volts. In the 20 MΩ range, the feedback resistor, Rf, is changed so that a 1-volt potential is maintained.

5.3 ANALOG-TO-DIGITAL (A/D) CONVERTER

5.3.1 The basic block diagram of the A/D Converter is shown in Figure 5-4. The analog-to-digital converison is accomplished by the quantized Charge-Balance technique. An Auto-Zero circuit minimizes the effects of offset and drift for greater accuracy. Filtering and Over-Voltage Protection circuits are provided at the input to the A/D Converter.

5.3.2 Time Base Counter

5.3.3 An External Clock signal (approximately 18 kHz) drives a Two-Phase Clock Generator. The clock frequency is divided by

the Time Base Counter into sampling intervals of 6144 pulses of which 4096 constitutes the measurement interval and 2048 for the auto-zero interval.

5.3.4 Auto-Zero Interval

5.3.5 During the Auto-Zero interval, the Input Amplifier is switched to circuit common. A pulsed Reference Current is supplied to the Integrator/Comparator by the Control Logic circuit. The Auto-Zero circuit equalizes the Integrator/Comparator input and maintains the equalizing current during the measurement interval.

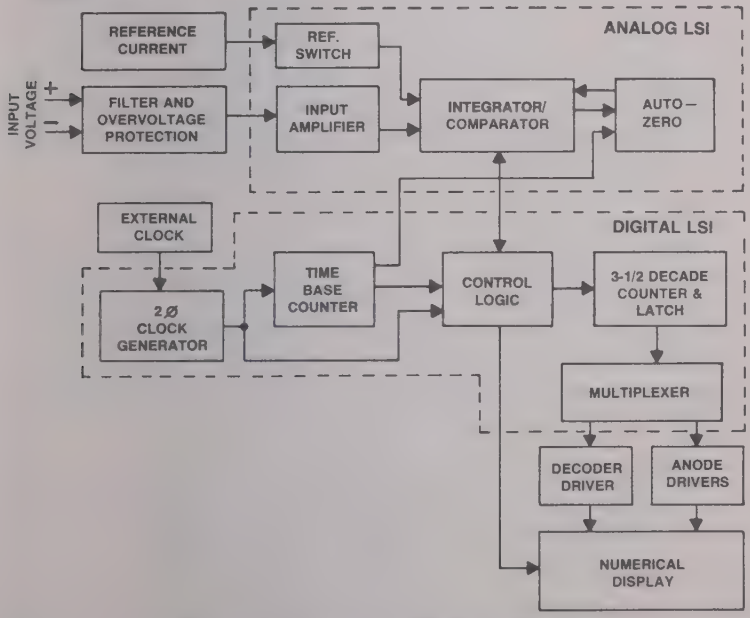


Figure 5-4. A/D Converter Block Diagram

5.3.6 Measurement Interval

5.3.7 The input voltage is now connected to the Input Amplifier through a switch actuated by the Control Logic circuit. The Integrator/Comparator senses an imbalance which the Control Logic circuit attempts to equalize by pulsing the Reference Current. During the equalization process, the Counter/Latch accumulates a count proportional to the magnitude of the input voltage.

5.3.8 Digital Information and Multiplexed Display

5.3.9 At the end of the measurement interval, the Latch is updated and the Counter is cleared. The Multiplexer routes the BCD and digit outputs into the Decoder/Driver and Anode Drivers. The BCD data are decoded into a 7-segment format which are connected to the cathodes of the display. The digit outputs controls the Anode Drivers which energizes the correct digit on the Numerical Display.

5.4 POWER SUPPLY CIRCUITS

5.4.1 AC Line Power: The AC line power is shown in Figure 6-2, Schematic Diagram. The incoming AC power is applied to the dual-primary power transformer T1. The primary winding is tapped for 240 VAC, 220 VAC, and 120 VAC operation. The secondary winding generates step-down voltages to provide 2 regulated and 2 unregulated DC voltages.

5.4.2 Regulated DC voltages of +12V and −12V are produced by two full-wave rectifiers, followed by two series-type voltage regulators. These regulated voltages are used to supply power to the analog circuits.

5.4.3 A full-wave rectifier, followed by capacitor C25, provides an unregulated +5V supply to all digital integrated circuits and

the LED display. An unregulated +15V supply is generated for operating the Resistance Converter.

5.4.4 Battery Power (464D only)

5.4.5 The battery-operated power supply of the 464D is shown on Figure 6-2, Schematic Diagram. With the POWER switch ON, the battery is connected to the input of the DC-TO-DC converter consisting essentially of T2 and transistors Q14 and Q15 in a multivibrator configuration. The multivibrator signal is coupled by T2 to the bridge rectifier and regulators to generate DC voltages of +12V, —12V, and +15V. The required +5 volt supply is provided by the battery.

5.4.6 The battery is charging whenever the 464D is connected to the AC line. A secondary winding from Transformer T1 and the associated rectifier provides power to operate a constant current source for charging the battery. The constant current source, consisting essentially of IC8 and Q19, provides a charging current of approximately 450 milliamperes when the Instrument is OFF. Approximately 50 milliamperes is supplied to charge the battery when the Instrument's POWER switch is set to ON.

5.4.7 When the 464D is operated with AC line power (no battery power) the battery-charging constant current source provides the +5V supply required for operation.

WARNING

These servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

SECTION VI
SERVICING INSTRUCTIONS

6.1 GENERAL

6.1.1 The 464 is carefully designed and constructed with high quality components. By providing reasonable care and following the instructions in this manual, the user can expect a long, useful service life from his Instrument.

6.2 COVER REMOVAL

6.2.1 The bottom cover can be removed for servicing purposes by the following procedures:

WARNING

Remove all power and connections to the Instrument before removing the case cover. Do not operate the Instrument with the bottom cover removed.

a. Depress the POWER switch to the OFF position.
b. Disconnect the line cord from the power source and all connections from the Instrument.
c. Pull out the knobs on sides of Instrument and raise the handle towards the rear of Instrument.
d. Turn the Instrument over and remove the four (4) screws within the rubber feet.
e. Lift bottom cover and remove handle.
f. Reverse this procedure when replacing the cover.

6.3 BATTERY INSTALLATION (464D only)

6.3.1 Refer to Table 6-2 for recommended batteries.

CAUTION

To avoid dangers associated with recharging batteries, use only the type specified in Table 6-2. Do not attempt to use cadmium zinc, alkaline or the like that is not designed to be recharged.

6.3.2 Install the cells as follows:

a. Remove bottom cover (paragraph 6.2). Remove the retainer tubings from the battery holder. Insert two cells into each retainer. Then install the combination into the holder. Ensure that the cells are installed according to the polarity orientation designated on the battery holder label. Failure to do so can damage the 464D.

b. Check that the battery contacts are clean and making good connection.

c. Replace the bottom cover.

d. For battery recharging, refer to paragraph 6.4, below.

e. Test the battery according to paragraph 4.3.2.

6.4 BATTERY CHARGING (464D only)

6.4.1 The battery is being charged at full rate when the POWER switch is set to the OFF position and AC power is applied to the Instrument. Approximately 16 hours are required to fully charge the battery in this mode of operation.

> **NOTE:** If the battery voltage checks below +4.7 volts, charge the battery with the POWER switch set to OFF for at least 15 minutes before operating the Instrument.

6.4.2 The battery is being "trickle" charged whenever the Instrument is operated by the AC powerline.

6.5 BATTERY CARE

6.5.1 Avoid discharging the cells completely. Check the battery voltage periodically using the BATTERY TEST jack (paragraph 4.3.2). Charge the battery whenever the voltage is close to or below +4.7 volts.

6.5.2 Do not operate the Instrument with discharged cells. Make sure to recharge all newly purchased batteries (paragraph 6.4) for at least 15 minutes before operating the Instrument.

6.5.3 Whenever the line cord is not connected and the Instrument is not in use, remember to set the POWER switch to the OFF position.

6.5.4 With nickel-cadmium cells installed in the 464D, avoid storing in an area where the temperature exceeds +60°C.

6.6 FUSE REPLACEMENT

6.6.1 The line and current fuses are mounted inside fuseholders on the main P.C. Board as shown in Figure 6-1. Use the following procedure to replace a fuse.

WARNING

Remove all power and input connections to the Instrument before removing bottom cover.

a. Remove bottom cover as described in paragraph 6.4.

CAUTION

DO NOT replace a blown fuse with a fuse which has a larger rating or slower time lag characteristic than those specified.

b. Carefully lift the defective fuse from the holder and replace with an appropriate fuse (Table 6-2).

c. Replace the bottom cover.

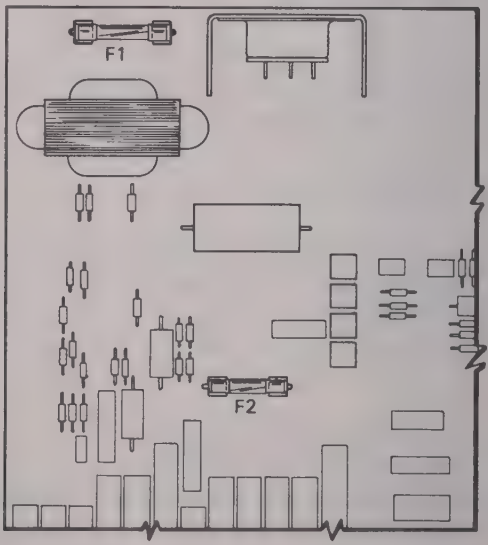


Figure 6-1. Fuse Location

6.7 TROUBLESHOOTING:

6.7.1 If the Instrument does not yield satisfactory results, follow this procedure, (and Troubleshooting Chart Table 6-1) before attempting servicing on the Instrument:

a. Review and comply with the Preliminary Notes and Checks, listed in paragraph 4.3.

b. Check the position on all switches for the parameter and range of value being measured and that the measurement situation is within the ratings of the Instrument.

c. If the 464A has been operated with AC power ensure that the power source is within the Instrument specifications, and free from excessive fluctuations and transients.

d. If the 464D has been operated with battery power, be sure that the cells are charged and properly installed (paragraph 6.4).

e. Ensure that the environment in which the Instrument is being used is within the Instrument specifications.

f. Inspect the device being measured and the measurement test set-up to ensure that proper shielding and grounding techniques have been used. Also, consider whether the Instrument is significantly affecting the circuit being measured.

6.7.2 If the steps taken in paragraph 6.7.1 do not yield satisfaction, refer to the troubleshooting chart (Table 6-1). Direct all other repair and adjustment needs to an Authorized Service Center. (A list of these centers appears at the back of this manual.)

Table 6-1. Troubleshooting Chart

Symptom	Probable Causes	Cure
1. No indication on numerical display when 464D is battery operated. AC operation is allright.	Cells - Discharged, defective, not installed properly, making poor contact, or missing.	Check battery voltage. Refer to para. 4.3.2. If OK contact nearest Authorized Service Center.
2. LOW intensity on numerical display in battery operation (464D).	Cells not fully charged.	Check battery voltage (para. 4.3.2). If battery checks low, remove cover and check that the cells are installed correctly and making good contact (para. 6.4). If they are, replace cover and charge battery overnight (para. 6.5).
3. No indication on the numerical display when Instrument is AC line operated (no cells installed).	a. Low or no voltage at power source receptacle. b. Line cord disconnected. c. Defective line cord. d. Line fuse open.	a. Restore correct voltage at power receptacle. b. Connect line cord. c. Repair or replace. d. Replace line fuse (para. 6.6).
4. Batteries do not respond to charge. 464D operation acceptable when connected to AC power.	Cells defective, not installed properly, making poor contact, or missing.	Remove cover and check that cells are installed correctly and making good contact (para. 6.4). If they are, check the voltages of the individual cells. Replace those which check significantly lower than normal (1.25 volts).

Symptom	Probable Causes	Cure
5. Operation normal on all functions and ranges except AC and DC Current.	Current fuse F2 open.	Replace fuse F2 (para. 6.6).
6. Indications fluctuate and/or drift, even though indication is OK at 000 with the input terminals shorted, and at 1000 counts when using a stable and low impedance input.	Fluctuations and/or drift are being generated by the device being measured or the measurement test set up.	Use proper shielding, grounding techniques and connections to minimize "pick-up" of unwanted signals due to ground loops, poor connections, and capacitive and/or inductive coupling. Operate Instrument (464D only) on battery for complete isolation from the powerline. NOTE: If the drift and/or fluctuation is coming from the device being measured, no cure is required, the measurement is valid, and the device must be corrected.
7. Indication is allright on battery; however, on AC operation, the reading fluctuates and/or drifts at 0, with the input shorted, and/or at 1000 counts using a stable and low impedance input. (464D).	AC power source is low or fluctuating (including transients).	Correct the power source or use Instrument on battery.
8. Same as 7 above, except indication acceptable on AC, but not battery operation.	a. Battery voltage low.	a. Check battery condition. Refer to para. 4.3.2. If allright charge bat-

Symptom	Probable Causes	Cure
		tery, refer to para. 6-4.
	b. One or more cells defective, not installed correctly.	b. Remove cover and check that cells are installed correctly and making good contact. If allright, replace all cells temporarily with conventional carbon zinc "D" size cells for checking purposes only. If problem still exists, contact nearest Authorized Service Center for instructions.
9. Slow response. Operation allright when using a low impedance input.	Parameter being measured has a high source impedance.	None required.
10. Accuracy not within specifications when checked with a stable, higher accuracy (at least 5 times better) low impedance (voltage measurements) source.	a. Instrument is out of calibration. b. Instrument not zeroed properly.	Contact nearest Authorized Service Center.
11. Accuracy of Instrument is within specifications but measurements appear in error.	a. Instrument affects circuit being measured. b. Common and/or normal mode specifications is being exceeded.	a. Study circuit being measured vs Instrument specifications. Correct indications accordingly. b. Refer to cure in step 6 above.

6.8 REPLACEMENT PARTS AND SCHEMATIC DIAGRAM

NOTE: This instrument must be serviced by qualified personnel. To aid in troubleshooting a schematic diagram is enclosed. The accompanied parts list (Table 6-2) describes the components and refers to Simpson part numbers. Reference Symbol numbers correlate the components shown on the schematic diagram with the parts list.

6.8.1 The following information is provided as an adjunct to the overall text contained in this manual and should be read and understood thoroughly prior to ordering replacement parts for the Instrument.

6.8.2 To obtain replacement parts, address order to the nearest Authorized Service Center (listed on the last pages of this manual). Refer to paragraph 2.3.1 for ordering instructions.

Table 6-2. Replacement Parts

( ) = Parts used on 464A only.

[ ] = Parts used on 464D only.

All other parts are common to both models.

Reference Symbol	Description	Part No.
	Battery, "D" size, 1.25V, 4-Ampere-Hrs, Nickel-Cadmium, Eveready Type CH4 Rechargeable, or Equal	1-113835

F1	Fuse, Line (for 120V operation): ¼A 250V Type 3 AG, Normal Blow	6-110301
	(for 240V operation): ⅛A 250V Type 3 AG, Normal Blow	
F2	Fuse, Current, 2.5A, 125V, Type 8 AG, Normal Blow	5-118087
[F3]	Fuse, 3.0A, 125V, Quick Acting Pico Fuse	5-115486
	AC Line Cord	5-118916
	Pushbutton, Black	5-118378
	Pushbutton, Red	5-118379
	Pushbutton, Gray	5-118086

C1	Capacitor, 3.3 pF, 1 kV	5-117138
C2,C23	Capacitor, Variable, 5.5-60 pF, 100V	5-116235
C3	Capacitor, 390 pF ±5%, 250V	5-118405
C4	Capacitor, 470 pF ±5%, 250V	5-118406
C5	Capacitor, 0.22 μF, ±10%, 630V	5-118449
C6,C8,C14, C15, (C18)	Capacitor, 15 μF, 16V	5-115534
C7	Capacitor, 0.01 μF, ±5%, 100V	5-117278
C9,C10,C17	Capacitor, 0.01 μF, ±20%, 50V	5-113215
C11	Capacitor, 47 pF ±10%, 160V	5-115992
C12	Capacitor, 0.33 μF, ±10%, 100V	5-118407
C13	Capacitor, 0.47 μF, 16V	5-115530
C16	Capacitor, 0.0022 μF, ±5%, 100V	5-117201
[C18]	Capacitor, 100 μF, 10V	5-117050
C19,C21	Capacitor, 0.033 μF, ±20%, 100V	5-117732

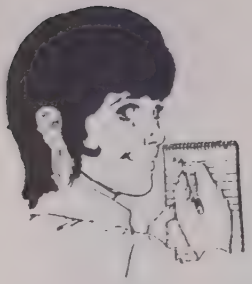
C20	Capacitor, 0.022 μF, ±20%, 100V	5-116188
C22	Capacitor, 0.1 μF, ±20%	5-113612
C24,C26	Capacitor, 470 μF, 25V	5-118408
C25	Capacitor, 2200 μF, 16V	5-118084
(C25)	Capacitor, 4700 μF, 10V	5-118083
C26	Capacitor, 10 μF, 25V	5-118426
C27	Capacitor, 100 μF, 25V	5-117737
C28,C29	Capacitor, 3.3 μF, 25V	5-118085
C30	Capacitor, 10 μF, 50V	5-116969
C31	Capacitor, 100 pF ±20%, 1 kV	5-113217
C32	Capacitor, 330 pF ±20%, 500V	5-112690
C33	Capacitor, 100 μF, 16V	5-118453
D1,D2	Diode, Silicon, 1N914 Selected	5-117379
D3,D8,D9, D10,[D19,D20]	Diode, Silicon, 1N914	5-112004
D4,D5,D6,D7 (D11,D12,D13) (D14,D15)	Diode, Silicon, 1N5059	5-113826
D16,[D17,D18]	Diode, Silicon, 10D1	5-114005
ZD1	Diode, Zener, 1N936	5-118918
ZD2	Diode, Zener, 1N5239B	5-118917
ZD3	Diode, Zener, 1N753A	5-112726
ZD4,(5)	Diode, Zener, 1N753A	5-112634
[RECT 1]	Diode, Bridge Rectifier, W005	5-115945
IC1	Integrated Circuit, Op. Amp., LM301AH	5-115916
IC2	Integrated Circuit, Op. Amp., LM308N	5-116598
IC3,[IC8]	Integrated Circuit, Op. Amp., SN72741P	5-115928
IC4	Integrated Circuit, Timer, NE555V	5-117150
IC5	Integrated Circuit, Analog, LD111	5-117724

IC6	Integrated Circuit, Digital, LD110	5-117723
IC7	Integrated Circuit, 7-Segment Decoder-Driver, DM7447N	5-115927
DS1,DS2,DS3	Readout, LED, 7-Segment	5-117338
DS4	Readout, LED, ±1	5-117337
Q1,Q2,Q10	Transistor, Silicon NPN, 2N4123	5-115931
Q11,Q12, Q13,Q18	Transistor, Silicon NPN, 2N4123	5-115931
Q3	Transistor, FET, N-Channel, 2N5458	5-112747
Q4,Q5,Q17	Transistor, Silicon NPN Darlington, 2N5306	5-115938
(Q20),Q6, Q7,Q8,Q9	Transistor, Silicon PNP, 2N3638	5-114106
[Q14,Q15]	Transistor, Silicon NPN, GET 2222	5-115934
Q16	Transistor, Silicon PNP, 2N5815	5-117720
Q19	Transistor, Silicon NPN Darlington, D40C1	5-118404
R1	Resistor, 9.90 MegΩ ±0.25%, 2W	5-118897
R2	Resistor, 90 kΩ ±0.25%, 1W	5-118897
R3	Resistor, 10 kΩ ±0.25%, 1W	5-118897
R4	Resistor, 0.01Ω	Assy. #10-650156
R5	Resistor, 0.09Ω	10-650156
R6	Resistor, 0.897Ω ±0.25%, 1.5W	5-118409
R7	Resistor, 9Ω ±0.5%, 1W	5-118410
R8	Resistor, 90Ω ±0.25%, ¼W	5-116272
R9	Resistor, 900Ω ±0.25%, ¼W	5-116273
R10,R11,R23	Resistor, 470 kΩ ±10%, ¼W	5-114983
R12	Resistor, 15 MegΩ ±10%, ¼W	5-118423
R13	Resistor, 100 kΩ ±10%, 2W	5-116883
R14,R17	Resistor, 10 kΩ ±10%, ¼W	5-113624
R15	Resistor, 22 MegΩ ±5%, ¼W	5-118424
R16	Resistor, 10 MegΩ ±5%, ¼W	5-116632

R18,R39	Resistor, 120 kΩ ±5%, ¼W	5-113627
R19	Resistor, 4.7 MegΩ ±5%, ¼W	5-118422
R20,R21	Resistor, 10 kΩ ±0.25%, ¼W	5-118413
R22	Potentiometer, 200Ω ±20%, 0.2W	5-118078
R24	Resistor, 448Ω ±0.25%, ¼W	5-118411
R25	Resistor, 4.08 kΩ ±0.25%, ¼W	5-118412
R26	Resistor, 100 kΩ ±10%, ½W	1-113949
R27	Potentiometer, 5 kΩ ±20%, ½W	5-118080
R28	Resistor, 37.5 kΩ ±0.5%, ¼W	5-118416
R29	Potentiometer, 1 kΩ ±20%, ½W	5-118079
R30	Resistor, 4.0 kΩ ±1%, ¼W	5-117695
R31,R32	Resistor, 36 kΩ ±1%, ¼W	5-118415
R33,R34	Resistor, 10 kΩ ±1% ¼W	5-114962
R73	Resistor, 330Ω ±5%, ¼W	5-116091
R36	Resistor, 470 kΩ ±10%, 2W	5-118421
R37	Resistor, 560 kΩ ±5%, ¼W	5-114984
R38,[R83]	Resistor, 100 kΩ ±10%, ¼W	5-115514
R40	Potentiometer, 10 kΩ ±20%, ½W	5-118081
R41	Potentiometer, 20 kΩ ±20%, ½W	5-118082
R42	Resistor, 75 kΩ ±1%, ½W	5-116921
R43	Resistor, 100 kΩ ±1%, ¼W	5-115506
R44	Resistor, 110 kΩ ±1%, ¼W	5-117519
R45	Resistor, 20 kΩ ±1%, ¼W	5-116621
R46,65,66	Resistor, 33 kΩ ±10%, ¼W	5-113875
R47	Resistor, 5.1 kΩ ±5%, ¼W	5-117714
R35	Resistor, 402 Ω ±1%, ¼W	5-116772
R48	Resistor, 15 kΩ ±5%, ¼W	5-116134
R49	Resistor, 10Ω ±5%, ¼W	5-115117
R50,51,52, R69,R74	Resistor, 100Ω ±10%, ¼W	5-114968
R53,54,55, R68,[72]	Resistor, 1 kΩ ±10%, ¼W	5-113871

[R56-62]	Resistor, Network, 100Ω ±5%	5-118094
(R56-62)	Resistor, Network, 68Ω ±5%	5-118425
R63,64,		
(R63,R64)	Resistor, 100Ω ±5%, ¼W	5-118419
[R67]	Resistor, 68Ω ±5%, ¼W	5-118419
(R67)	Resistor, 47Ω ±10%, ¼W	5-114967
R70	Resistor, 220Ω ±5%, ¼W	5-117179
[R71]	Resistor, 270Ω ±10%, ¼W	5-114969
R75	Resistor, 68 kΩ ±5%, ¼W	5-115962
R76	Resistor, 750Ω ±5%, ¼W	5-116366
R77	Resistor, 22 kΩ ±5%, ¼W	5-117196
R78	Resistor, 27 kΩ ±5%, ¼W	5-118431
[R79]	Resistor, 390Ω ±5%, ¼W	5-118420
[R80]	Resistor, 18 kΩ ±10%, ¼W	5-115512
[R81]	Potentiometer, 1 kΩ ±30%, ¼W	5-114069
[R82]	Resistor, 0.5Ω ±1%, 1W	5-113998
	Switch, pushbutton, 12 Station	6-110823
(T1)	Transformer, Power 464A	5-119145
[T2]	Transformer, DC-DC Converter	5-118377
[T1]	Transformer, Power 464D	5-119391

NOTES



NOTES

FOR THE RECORD

Date Purchased: _____

Purchased From: _____

Identification Number: _____

Date	*Type of Service*	*Serviced By*
____	_____	_____
____	_____	_____
____	_____	_____
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____	_____	_____
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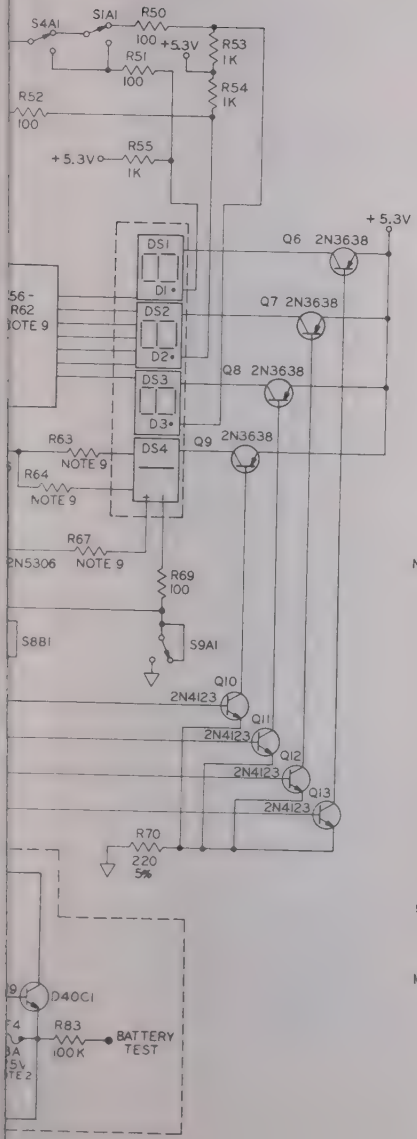
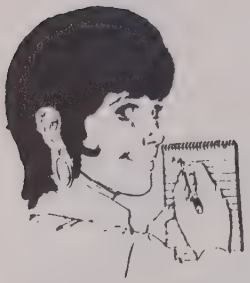


NOTES

1. LINE VERSION ONLY. MODEL 464A
2. BATTERY VERSION ONLY. MODEL 464D
3. LINE VERSION - JUMPER
   BATTERY VERSION - .5Ω, 1%
4. ALL SWITCHES SHOWN IN OUT POSITION.

S1 - 2	S7 - KΩ
S2 - 2	S8 - DCV
S3 - 20	S9 - DCI
S4 - 200	S10 - ACV
S5 - 2000	S11 - ACI
S6 - 20MΩ	S12 - POWER

5. ALL RESISTORS 1/4W, 10% UNLESS OTHERWISE STATED.
6. CAPACITORS IN μfd.
7. MAKE BEFORE BREAK CONTACTS.
8. FOR 120V CONNECT POWER LINE TO TERMINALS 1 & 2, F1=1/4A
   FOR 220V CONNECT POWER LINE TO TERMINALS 1&3, F1=1/8A.
   FOR 240V CONNECT POWER LINE TO TERMINALS 1&4, F1=1/8A
9. LINE VERSION: R56-R64 = 68Ω, 5%
   R67 = 47Ω
   BATTERY VERSION: R56-R64 = 100Ω, 5%
   R67 = 68Ω, 5%
10. R1, R2 AND R3 ARE RATIO MATCHED TO ±.05%.



NOTES

FOR THE RECORD

Date Purchased: _____

Purchased From: _____

Identification Number: _____

Date	*Type of Service*	*Serviced By*
____	_____	_____
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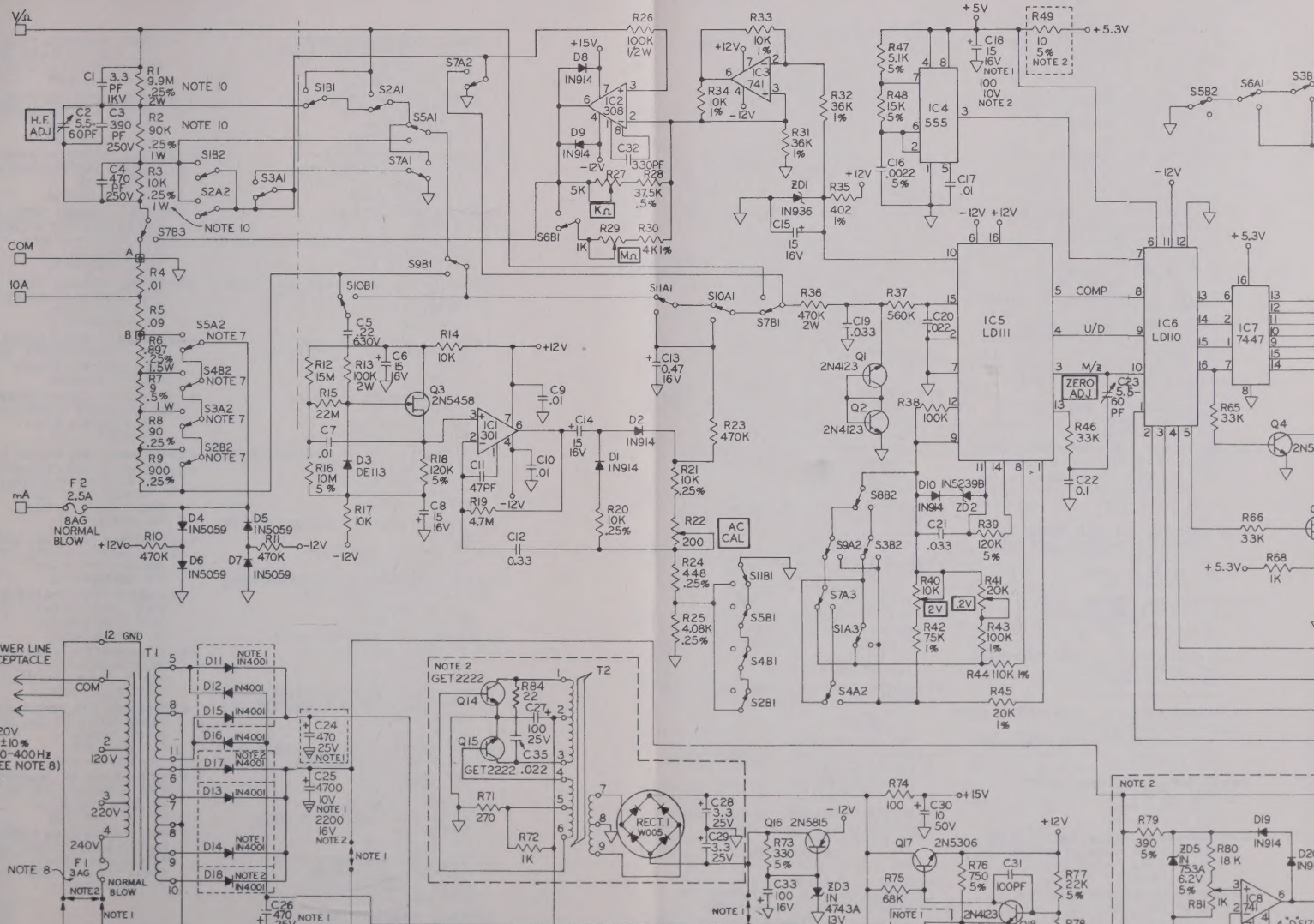

Figure 6-2. Schematic Diagram

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